Ukrainian Journal of Ecology

Ukrainian Journal of Ecology, 2020, 10(6), 255-268, doi: 10.15421/2020_291

ORIGINAL ARTICLE

Pre-sowing seed treatment in winter wheat and spring barley cultivation

V.V. Bezpal'ko[2], S.V. Stankevych[1], L.V. Zhukova[1], I.V. Zabrodina[1], V.P. Turenko[1], V.V. Horyainova[1], A.A. Poedinceva[1], O.M. Batova[1], O.Yu. Zayarna[1] S.V. Bondarenko[1], M.M. Dolya[3], R.M. Mamchur[3], P.Yu. Drozd[3], V.V. Sakhnenko[3], A.V. Matsyura[4]

[1] *Institute of Horticulture, National Academy of Agrarian Science of Ukraine [1]V.V. Dokuchaev Kharkov National Agrarian University, v. Dokuchaevske, Kharkiv region, 62483, Ukraine*
[2] *Petro Vasylenko Kharkiv National Technical University of Agriculture, Kharkiv, 61002, Ukraine*
[3] *National University of Life and Environmental Sciences of Ukraine, Kyiv, 03041, Ukraine*
[4] *Altai State University, Barnaul, Russian Federation*
**Corresponding author E-mail: sergejstankevich1986@gmail.com*

Received: 14.10.2020. Accepted 26.11.2020

The increase in the cereal spike crops yield capacity under the current change of the climatic conditions in Ukraine will have a positive tendency in the nearest future, but the sustainable grain production under sharp weather fluctuations is possible only with the improvement of the agro-technological systems. The pre-sowing seed treatment with chemical synthesis pesticides remains the main method in the agricultural industry today. However, the pesticides inevitably have a negative influence on the ecosystem of any level. A more environmentally friendly method of seed treatment under the intensive technology is the combination of the microwave seed irradiation and seed incrustation with the plant growth regulators that provide an increase in the cereal crops yield capacity up to 15–20 %. It is possible to reduce the negative influence of chemical measures on the quality of the cereal crops seeds by using for the seed treatment a mixture of a treatment agent with the preparations having the stimulating properties. The most promising among all physical methods of the pre-sowing seed treatment is the microwave technology which suppresses the entire complex of the seed infection and can become an alternative to the chemical method of plant protection. The universal character and practical importance of MW technologies in combination with the growth regulating substances consist not only in the increase in the yield capacity of the field crops, but also in reducing the technogenic load on the environment. The peculiarity of EMF of EHF application in the agricultural production is the necessity to take into account the specific electro-physical, technological and biological properties of the crops, which high heterogeneity greatly influences the action of the electromagnetic energy and the final result.
Key words: disinfection, pathogens, seeds, grain, winter wheat, spring barley, microwaves.

Introduction

Increasing the crop yield capacity and improving the product quality are one of the most important tasks for agricultural scientists in many countries all around the world. Cereal crops form the basis of the agricultural production. They are the most valuable and most common in the world among all field crops. The cereals and legumes make up about 70% in the structure of food products. Grain production in the world is increasing mainly due to the improvement of varietal resources and the modernization of zonal technologies for growing cereals, including wheat, barley, rye, and oats.

Wheat always has been and still remains the leading grain crop in the world and in Ukraine. The total area under this crop occupies about 240 million hectares in the world and 7 million hectares in Ukraine. In 2017 the world wheat production amounted to about 750.1 million tons, and in Ukraine it was 21 million tons. It is natural that wheat is a staple food product in 43 countries with a population of more than 1 billion people (Adamenko, 2008).

The total share of Ukraine in the world production of spring barley grain is about 8.2 % (Sajko, 1997). Barley is an indispensable component for the production of mixed feed and raw materials for the food and brewing industries.

In Ukraine the stable grain production in the second half of the 1990s was characterised by an average annual bulk yield of 50–52 million tons, which is almost 1000 kg per capita (Babich et al., 1994). However, the sharp climatic changes (mostly in the form of temperature rise, a tendency that has been observed in the last two decades) have led to fluctuations in agro-meteorological conditions for growing cereal crops. During the droughts of 2008–2009 the world wheat grain production decreased significantly. The drought in these years has affected the countries that are the main exporters of grain, namely Australia, Argentina, Brazil, Canada, and Eastern Europe as well as Ukraine. As a result the global demand for food grains has increased.

Only during the last seven years the food grain shortage has constituted 310 million tons on the average (Sajko, 2008). Therefore, grain production has been and still remains a priority in agricultural development.
The world experience shows that in the countries with high levels of agro-technical support the increase in grain yield reaches a critical limit. The use of "intensive" technologies in agricultural crop production since the 1980s of the last century has led to a sharpening of the contradictions between the economy and the environment. The intensive application of pesticides and mineral fertilizers in agriculture, including chemicals for the pre-sowing seed treatment, and increasing the productivity of plants inevitably cause a number of undesirable effects of ecological and economic characters.
One of the obligatory elements of the technological process of cultivating cereal crops, which affects the increase in the yield and quality of crop production, is the pre-sowing treatment of seeds with chemical and biological products of different origin. But today in Ukraine the problem of seed sanitation and selection of the most viable biotypes with high productive properties by the pre-sowing treatment with the ecologically friendly methods have not yet been solved.
The search for new alternative methods for seed disinfection in order to reduce the negative influence of agrochemicals on the environment has been recently carried out in Ukraine and abroad. The physical methods such as the treatment with ozone, microwave and ultrasonic radiation, etc. are of great interest (Shevchenko et al., 2007).
One of the most ecologically friendly and cost-effective methods of pre-sowing seed treatment is irradiation with extra-high frequency microwave field (MWF of EHF). Along with the physical method of seed treatment with the microwave field, the plant growth regulators and biological preparations which are used to increase the resistance of plants to the adverse factors and the yield capacity of many crops have become widespread in the agricultural practice (Anishin, 2002).

Material and methods

Modern literature sources on methods of disinfection of wheat and barley seeds from pathogens are analyzed.

Results

Peculiarities of modern technologies of winter wheat and spring barley cultivation in the Eastern Forest-Steppe Zone of Ukraine
Cereal crops form the basis of human food production. The cereals are the most valuable and most common crops among all other field crops in the world where there is the crop farming. According to the sowing area, wheat occupies the first place in the world, and rice ranks the second place (Sajko et al., 1994).
Obtaining high and stable grain yields depends on a number of factors and techniques needed to grow crops, beginning from soil preparation and sowing to harvesting.
Different technologies of winter wheat and spring barley cultivation are used in the modern plant growing of Ukraine; the most known of them are the intensive, resource-saving, biological (organic) and No-till ones.
It is the structure of the technology that influences the economic indices, the ecological situation and the soil condition. The main elements of cereal crops cultivation technologies are scientifically grounded crop rotations, the use of high-productive, adapted to the specific environmental conditions, resistant to lodging and seed shedding varieties as well as providing the plants with nutrients and protecting them from the diseases, pests and weeds (Bojko & Kovalenko, 2007) All agro-technical techniques of spike crops cultivation should be rigidly differentiated depending on the soil and climatic conditions of the growing zone (Samdelle & Read, 1968).
The optimum selection of the best predecessors in crop rotation and their alternation allow regulating the nutritional and water regimes of the soil, which have a positive influence on the yield capacity and grain quality (Orel & Bojko, 1975).
High and stable winter wheat yields in the Forest-Steppe Zone are provided by such predecessors in crop rotation as the fallow lands, perennial grasses for one mowing, vetch and oats mixtures for the green fodder and hay, corn for the green fodder, and peas for grain. It is also possible to sow cereals after buckwheat, oats, and sunflower.
Due to the proper placement of spring barley in the crop rotation, its yield capacity increases up to 37 % on the average (Pikush & Bondarenko, 1985). The best predecessors in crop rotation on the black soil are the hoed crops, namely sugar beet or corn for grain. It is not desirable to reseed brewing barley with the perennial legumes, as this leads to an increase in the protein content and a decrease in the starch content in the grain (Lebed et al., 1992).
Improving the productivity of modern winter wheat and spring barley varieties in the conditions of unstable moisture depends on the rational use of mineral fertilizers. The terms and rates of the fertilizers applying are adjusted to weather conditions and vegetation phases. The optimum ratio of the separate elements is determined taking into account the agrochemical properties of the soil and the coefficients of nutrient removal by the cultivated plants (Melnik & Trocenko, 2008).
According to the scientific data the share of the fertilizers in the yield formation is 30–40%, which is much higher than the share of the seeds, plant protection measures or soil tillage (Anbessa et al., 2009).
When growing according to the intensive agricultural technology, winter wheat requires more nitrogen fertilizers than other crops. The potassium fertilizers in the whole amount, the main part of phosphorous fertilizers and 20–30 % of nitrogen fertilizers from their total amount are applied before the basic tillage of the soil, since under their simultaneous embedding the efficiency increases 1,5 times in comparison with their separate application (Avramenko et al., 2016).
Due to the significant leakage of the nutrients into the deeper soil layers the conducting of spring nitrogen fertilization of winter crops at a total rate of 100–130 kg/ha of active substance is a very important and obligatory measure (Lihochvor, 2006).
To obtain the winter wheat grain meeting the requirements of 1–2 grades of quality, the optimum nitrogen nutrition at the beginning of the growing season and especially during the period when the intensive protein synthesis in the caryopsis is taking place is necessary. The basic application of the fertilizers and early spring nourishment contribute to the increase in the yield, but in most cases they do not provide plants with nitrogen enough to form high protein grains. It is possible to improve the

grain quality due to the additional foliar fertilizing of plants with a solution of urea or urea and ammonia mixture at the rate of N_{15}-N_{20}, which allows to increase the content of crude gluten by 1,0–1,5 %. (Popov et al., 2014).
Spring barley is very fastidious as for the soil fertility, which is explained by the short vegetation period (up to 100 days) and the super-fast assimilation of nutrients, as well as by the underdeveloped root system with the low assimilation of inaccessible forms of nutrient compounds especially in the initial periods of growth and development. Therefore, an important condition for the intensive growth and development of the plants is their sufficient supply with the readily soluble compounds of nutrients at the initial stages of ontogenesis and application of the fertilizers under the barley crops beginning from the sprouting and to the stalk shooting.
Mainly simple mineral fertilizers such as ammonium nitrate, urea, ammonia water, ammonized superphosphate, and also the compound fertilizers, namely nitro-ammophoska, super-agro and others are applied into the soil under the spring barley crops before the pre-sowing tillage. The compound mineral fertilizers have the advantage when applying into the rows simultaneously with the sowing. For this purpose nitro-ammophoska, super-agro, nitrophoska, ammophoska and other fertilizers are applied. The compound mineral fertilizers of a pair combination (super-agro of $N_{20}P_{10}$ brand, ammophos of $N_{12}P_{50}$ brand, and ammophosphate $N_{16}P_{20}$ brand and others) are applied in the soils with high content of the exchange potassium (Lihochvor, 2006).
The application of nitrogen at the early phases of plant development contributes to the accumulation of carbohydrates in the grain, and later (from the ear formation phase to the ripening one) it contributes to the accumulation of protein. But according to some authors any rate of nitrogen increases the protein content in the grain more than the yield capacity, especially on the black soil (Secnjak & Kindruk, 1984). But other authors consider that nitrogen fertilizers are the most effective on the black soils (Reddy et al., 1986). Thus, with sufficient moisture the yield capacity increases sharply and the quality of the grain changes slightly; and in the years of droughts the reverse process is observed. Low rates of fertilizers help to increase the grain size, which is important for its brewing properties (Shurley, 1987). The main task of soil tillage for the winter crops in the arid conditions of the autumn period is the accumulation and preservation of 20–30 mm of productive moisture in the arable layer of the soil in order to obtain even seedlings and subsequent tillering (Belaev et al., 1985).
The modern soil tillage systems are an important component of the cultivation technology. The exacerbation of the environmental problems in Ukraine and in several countries of the world dictates the necessity to look for the alternative crop farming methods. These are the transitional systems of crop farming, namely the grain, green manure, rotation cropping system, and grassland ones (Belaev et al., 1985). The saturation of crop rotations with the cereal crops which is characteristic of the intensive technologies, has led to a significant decrease in the soil fertility, weed infestation of the crops, and deterioration of the water regime of nourishment (Kravchenko et al., 2004). Surface soil tillage facilitates the more intensive work of cellulose-destroying bacteria, which increases the formation of the available nutrients for the plants, and therefore increases the reserves of the productive moisture and nutrients in the soil through the crop residues left in the field. At the same time the economic and energy indices of productivity are improving, but the crop infestation with the weeds, especially with the perennial offset weeds is increasing (Gulidova, 2001).
In the system of basic soil tillage for the spring barley crops the ploughing at the depth of 20–22 cm is carried out immediately after harvesting of the predecessor, namely the hoed crops; and the preceding soil disking is necessary after growing corn for grain aimed at better embedding of the crop residues (Matveev et al., 2003). After the soil mellowness in the spring the harrowing is done in order to save the water in the soil and then the pre-sowing tillage is carried out in the case of spring barley. It is very important to prepare the soil for sowing in a quality and timely manner; it is an important element of the resource-saving technologies (Fyodorova et al., 1989). The pre-sowing soil tillage for all crops, and especially for the early-spring crops, should contribute to the maximum preservation of water and the destruction of weeds (Popov et al., 2007).
The proper selection of a variety takes an important place in the technology of growing winter wheat and spring barley in the conditions of the Forest–Steppe Zone of Ukraine. By selecting the most valuable varieties it is possible to significantly improve the yield capacity and quality of winter wheat grain (Fyodorova et al., 1989; Sherbakov, 1998).
For the successful cultivation of spring barley it is necessary that the selected variety should have a number of characteristics that correspond to the soil and climatic conditions of the zone (drought resistance, length of the vegetation period, disease resistance, resistance to lodging, plant height) (Kirichenko et al., 2002).
To obtain the high yields of winter wheat and spring barley it is necessary to provide the optimum number of plants and productive stems per unit area, which is achieved by the appropriate seeding rate depending on the cultivation area, the level of crop farming culture, the rate of fertilizers, soil fertility, variety and other factors (Fyodorova et al., 1989). The optimum plant density and sufficient number of nutrients in the soil are the most important conditions on which the sowing productivity depends (Musatov et al., 1980). It is known that the optimum seeding rate for the Forest–Steppe Zone is 4.0–5.0 million pieces/ha, but it can vary from 3.5 to 5.5 million pieces/ha. The seeding rate of spring barley in production varies from 3.0 to 7.0 million pieces/ha depending on many factors (Fyodorova et al., 1989). Timely sowing provides the most favourable conditions for the development of plants and the use of all factors in order to obtain a high grain yield with the best quality indices (Skidan et al., 2005). Over the past 10 years the tendencies regarding the rise in temperature have accelerated. According to the Kharkiv Regional Center for Hydrometeorology the average daily temperature in the region over the 17 past years has increased by 0.7–2.5 °C depending on the month in comparison with the average data for the period of 1951–1993. The average daily air temperature in July–November (especially in October and November) also increased significantly during the above-mentioned period. A rise in the sum of effective temperatures (above +10 °C) ranges from 5.1 °C in July to 103.7 °C in August. During the periods of sowing, sprouting and autumn development of winter plants (September–October) this index was 22–35 °C above the norm (Popov et al., 2007).

In this connection the optimum sowing dates for winter wheat have shifted to a later period: from the 5th to the 20th of September, and the admissible dates are until the 25th of September (Popov et al., 2007). The sowing of spring barley begins early in the spring when the mellowness of the soil is reached. One day delay from the optimum time leads to a shortage of 0.05–0.1 t/ha of grain, and in the arid spring the shortage increases by 2–3 times (Popov et al., 2007).
The integrated plant protection from the weeds, pests and diseases is one of the priority tasks of the agricultural techniques complex that provides the fullest usage of the biological and climatic potential and genetic possibilities of the variety (Gorban, 2013). Its basic principles are as follows:
– high level of agricultural technology which provides the formation of healthy plants;
– use of varieties resistant to the adverse conditions;
– taking into account the economic thresholds of harmfulness.
This fact gives the opportunity to narrow the gap between the potential and actual plant productivity. The introduction of the integrated protection system provides obtaining the additional high quality grain yield up to 0.5–1.6 t/ha while reducing the application of chemicals by 15–30. At the same time the application of the biological stimulants is advisable (Gorban, 2013).
The methods for the protection of winter wheat and barley spring agro-biocoenosis are being sought; they suggest a significant reduction in the pesticide application. Thus, in the researches regarding the Myronivska 61 variety (1992–1995) the pesticide protection system (5 chemicals) provided an increase in the yield by 0.77 t/ha, and an alternative system (the use of the growth regulators and biological preparations AGAT-25, Biomix, Rizoplane and Tour as well as the Dialen herbicide) not only reduced the growth, but also provided its increase of up to 1.08 t/ha (Derecha & Dazhuk, 1997).
According to the Myroniv Institute of Wheat named after V.M. Remeslo of the National Academy of Agricultural Sciences the yield capacity under the common technology (without applying pesticides) was 5.79 t/ha, and under the intensive technology (7 chemicals) it increased up to 6.92 t/ha, and under the resource-saving technology, when two pesticides were used, the yield capacity decreased by only 0.22 t/ha and amounted to 6,7 t/ha (Kisel, 1997). The research carried out by V.V. Likhochvor showed that in 1991–1993 while using the intensive technology, the yield capacity was 7,23 t/ha on the average, and while using the resource-saving technology it was 7.16 t/ha (Lihochvor, 1993).
In the latter technology the rate of the fertilizers is reduced by half, and only the chemical preparations Dialen and Retardant Tour have been applied. The most important feature of the intensive technologies today is the biologization of the technological processes; it is the use of the crop rotation opportunities, variety, rational fertilization system, integrated plant protection, soil preparation depending on its fertility, as well as the use of plant growth regulators (Kisel, 1997). The pre-sowing seeds infestation with the chemical plant protection agents or seed treatment is one of the obligatory elements of all technologies of growing the cereal crops in the Eastern Forest–Steppe Zone of Ukraine. Seed treatment is an effective way of protecting plants from the seed and soil infections, and at early stages of plant development it is a measure preventing the aerogenic infection (Retman, 1998). However, as a number of the results of the scientific researches and the experience of their practical use indicate, the chemical measures of protection should be limited, and they can be used only if objectively necessary (Popov et al., 2014).
Over the last 30 years the significant increase in the yield capacity of the agricultural crops while using the intensive technologies has led to a threatening environmental problem, namely a contradiction between the economy and the environment. The widespread application of the fertilizers and chemicals for the protection of plants against the pests, diseases and weeds has caused the environmental pollution, and as a result there were the deterioration of the quality of the crop production and a negative impact on human health (Lihochvor, Petrichenko, 2006). In this connection today the pre-sowing seed treatment is one of the most important methods directed at the relatively smaller number of the applied active substances providing the necessary crop protection and it has the greatest protective effect against a wide range of the pathogens and insect pests.
The pre-sowing seed treatment is interesting not only from the standpoint of economy, but also it is interesting from the standpoint of ecology: in comparison with spraying the area under cultivation is significantly reduced. For example 10,000 m^2 of soil is processed when spraying 1 hectare; at the same time the active substances are applied in a continuous manner while under the soil treatment the area is significantly reduced. In addition the seed treatment influences the objects not having a special purpose to a less extent; it is not wind-blown, that is, less weather dependent and is an important element of the integrated plant protection. At the same time despite all the advantages over other methods of pesticide application, the pre-sowing treatment of seeds with the chemical disinfectants remains a source of the environmental pollution in Ukraine.
Theoretical bases, tasks and development of technologies of pre sowing seed treatment in Ukraine
The history of the world agriculture shows that fungi, bacterial and viral diseases, weeds, harmful insects and nematodes can dramatically reduce the gross production and product quality, and in some cases even completely destroy the crop. According to FAO the world crop losses of basic crops caused by the harmful organisms amount to 21 % regarding the diseases; the losses caused by the pests constitute 11 %, and in the case of weeds this figure reaches 24 % (Sekun et al., 2007).
In Ukraine, the average annual crop losses caused by the diseases, pests and weeds make up 20–30 %; in the case of wheat it is 27 %. Therefore, even partial loss prevention is an important factor in significant improvement of the crop productivity.
According to the Institute of Plant Protection of the National Academy of Agrarian Sciences of Ukraine, the fungi of the *Alternaria, Fusarium, Drechslera, Bipolaris, Penicillium* genera and others are present on the seeds (Yevtushenka & Maryutin, 2001). Very often there are two or more types of fungi on one seed, but the features of their development are quite different, so they do not allow introducing the thresholds of harmfulness (Gorban, 2013).
The phytosanitary situation is so unpredictable that to leave the seeds thrown into the soil without treatment, means to brush 60–70% of the future yield aside. The pathogenic organisms that are capable of generating a number of plant diseases at the initial stage of plant development and growth, most notably bacterioses and mycoses, cause the most significant losses to the farmer (Lisovyj, 1999).

For the first time the seed treatment (probably with sodium chloride) against Common smut of wheat was described by Remnet in 1637. In 1733 Briton Tell mentioned the treatment of cereal crops seed with the salty seawater. It happened by accident. In 1660 a ship carrying a load of wheat sank near Bristol. Some of the grain was rescued but, since it had been soaked in the salt water, it was not ground into flour, but used as the sowing material. So the peasants noticed a profitable difference between "salty" and ordinary crops (Fokin, 2009).

In addition to copper, mercury compounds and formaldehyde, quite a large number of the chemical compounds (acids, alkalis, salts of light and heavy metals, phenols, cresols, resins, organic paints, and the substances that released active chlorine) were used as the treatment agents. On the 1st of September 1926 the "Plant Protection Service" of Germany made a list of 14 trade marks deserving the attention (in general, the Germans began to hold such a competition since 1923). Essentially, it was the first recommended list of the treatment agents, a prototype of our domestic "List..." (Perelik pesticidiv…., 2018).

Dry, semi-dry, wet seeds and wet treated seeds are used in practice depending on the preparation, the biology of the pathogen, the structure and other features of the seeds (Fokin, 2009).

The dry disinfection is the uniform application of dry powdered preparations to the seed surface. The advantages of this method are the easiness of execution and the disadvantages are the poor technical efficiency due to poor adhesion of the treatment agent to the seed and keeping on it. This method is the most ecologically dangerous and leads to the significant environmental pollution (Prishepa, 1998).

The semi-dry treatment is the application of water suspensions or disinfectant solutions to the surface of the seeds at the rate of 20–30 L/t, followed by 3–4 hours of soaking, ventilation and drying. The advantage is the high efficiency of infection elimination and the disadvantages are the increase in water content in the seed, considerable labour intensity and low productivity (Prishepa, 1998).

The wet treatment involves strong moistening or soaking in a liquid (solution, suspension, or emulsion) of the treatment agent, followed by 2-hour soaking, ventilation, and drying. The advantage of this method is the high technical efficiency, and the disadvantages are the necessity for further drying, and high labour intensity (Prishepa, 1998).

Nowadays in many countries of the world the seed treatment is not only a necessary but also a legally obligatory measure of agricultural crops protection. According to the Irish experts up to 50% of winter wheat seedlings in the region die because of the root rots since they were not treated before sowing (Strona, 1984).

The treatment with the modern preparations makes it possible to disinfect the seed from the external and internal infection, protect it and the seedlings from the soil pathogens, as well as to reduce the negative effect of traumatic injury due to the activation of its protective properties and prevent the pathogens development (Fokin, 2009).

Back in the 80's of the last century, unlike the existing technologies of the pre-sowing seed treatment, more ecologically-friendly technologies were developed. The technology of the pre-sowing seed treatment called "incrustation" was developed at the Plant Production Institute named after V.Ya. Yuryev. It combined the treatment itself and creation of a protective seed coat (Dindorogo & Strona, 1989) The efficiency of treatment under this technology is substantiated not only by the influence of the treatment agent, but also by the formation of a protective coating on the surface of the seed, which prevents the access of soil microorganisms to the seeds through the micro-trauma of the endosperm or germ.

According to the authors of the researches carried out using the Vitavax 200 FF and Raxil Extra seed treatment agents, the development of root rots at the stage of autumn tillering of winter wheat in the cases without any treatment was higher than the economic threshold of harmfulness (ETH); it was in the range of 18,5–19,7 %. In the arid years in the cases when using the Vitavax 200 FF and Raxil Extra treatment agents this figure was lower by 15–34 % respectively, and in the humid years it was 60–65 % lower. Thus, when sowing the treated seeds, the development of root rots was lower or close to the economic threshold of harmfulness (Krasilovec et al., 2014). Some researchers point out that the fungicides contribute to the growth and development of plants, while others in their work show a negative influence of systemic fungicides on germination and the intensity of the initial plant growth (Batalov et al., 1989). M.I. Zazimko and others indicate that during the researches carried out for 11 years with 47 field experiments, only 12 of them gave the significant increase in the crop yields after the pre-sowing treatment of winter wheat seeds (Zazimko et al., 1996). At the same time the treatment agents provide quite effective protection of plants at the beginning of the vegetation period but remaining a source of the environmental pollution; they are absorbed by the grain and stored products and have a negative affect on human health (Babayanc, 2014).

According to a number of authors the use of chemicals for the pre-sowing seed treatment inhibits the vital activity of the germ, weakens the productivity of plants and creates an environment for lowering the immunity during the vegetation period (Babayanc, 2014). Such measures are not compatible with the environment and the quality of food products. Therefore, the problem of developing and researching new ecologically friendly methods for the pre-sowing seed treatment allowing to minimize the energy costs and to achieve an increase in the yield capacity is still quite urgent. Particularly in Ukraine, almost all territory of which is declared a zone of environmental disaster, the widespread use of chemicals can lead to the unpredictable results (Storchous, 2013).

In practice there is a separation of the pre-sowing treatment methods depending on the functions they perform. To activate the growth processes in the seeds the electro-physical methods are used; to remove the viral infections and at the same time to improve the sowing qualities the thermo-chemical methods are used; to sanitise the seeds from the fungal and bacterial pathogens the chemical method is preferred (Zubova, 2013). Among the ecologically friendly methods of the pre-sowing seed treatment are the thermal methods that are applied to the seeds of different agricultural crops in order to increase their germination and reduce the infection caused by the pathogenic microflora. This type of action includes the hydrothermal treatment of seeds and stratification (keeping the seeds at a constant temperature for a long period). Due to the heat treatment of seeds (1–2 hours at a temperature of 70–80 °C) their infection with the virus, alternaria blight, bacteriosis and phomosis decreases; the germinating power and sprouting energy increase.

The seed treatment with the heated steam at a temperature of 150 °C also improves the germinating power. But the disadvantage of the thermal method is the processing time of the sowing material (from several hours to several months), as well as the high energy intensity and multistage process (Kirichenko et al., 2009). The photo-energy methods, which are used to stimulate the growth processes, are applied both to the seeds and to the vegetative plants. The pre-sowing seed treatment with the pulsed focused solar irradiation increases the yield capacity up to 11 %, and treatment of the vegetative plants increases the intensity of the photosynthetic processes (Dubrov, 1963). The photo-energetic methods also include laser treatment of the plant seeds during the vegetation period (Kratzsch et al., 1997).

There are also other ecologically friendly, highly effective methods of the seed treatment. They are low-frequency electromagnetic field (the Tbilisi State University); pulse concentrated sunlight (the Kazakh Agricultural Institute); infrared radiation (the Siberian Research Institute of Mechanization and Electrification of Agriculture); hydrogen and plasma treatment (VSRI of Agricultural Electrification); gradient magnetic field (Joint Institute for Nuclear Research, APhI), and others (Sherbakov, 2002); extra high frequency (EHF) of microwave field irradiation (MFI) (the Odessa Selection and Genetic Institute, the Kharkiv National Technical University of Radioelectronics and the Plant Production Institute named after V.Ya. Yuryev of NAAS) (Bezpalko, 2016).

The effect of the EMF of EHF range on the agricultural crops seed leads to the activation of biosynthesis processes and the accelerated cell division processes, as well as to the restoration of the connection and functions disturbed by the diseases (Pushkina et al., 2012).

The advantages of using the microwave energy in agriculture are explained by the selectivity of the conversion of the electromagnetic energy into the thermal one, by greater depth of the field penetration, efficiency and economy (Pushkina et al., 2012). The method is ecologically safe because the irradiation absorbed by the treated plant directly influences the processes of the plant vital activity, but at the same time no ecologically harmful substances get into the environment (Shamgunov & Stepura, 2017). Depending on the irradiation rate applied to the seeds, the enzyme reactions can cause both stimulatory and inhibitory effects. The stimulating rates accelerate the growth, and change the physical and chemical state of the cells, the air-tightness of the seed coat and other metabolic reactions. Overrates cause the disruption of the intracellular structures, which requires some cost to restore them (Shamgunov & Stepura, 2017).

The mechanism of energy transmission by the electric and magnetic fields is associated with the free and bound water in the seed, which are the receiver and transmitter of the irradiation energy. The peculiarity of the water activated with the magnetic field is the presence of freely directed energy with the random nature of changes in magnitude and frequency in it. The method of the pre-sowing seed treatment with MWF of EHF is founded (based) on the stimulation of the regulatory system of the germ, which allows removing the seeds from the state of physical rest, resulting in the accelerated cell division during germination of the seeds. The treatment of cereal crops seeds with the EHF rays is considered to be one of the most promising agricultural measures that stimulates the plant growth and development, increases plant resistance to stress factors, and increases the soil nutrient utilization coefficient, which leads to the increase in the yield capacity (Hasanov et al., 2010).

When an object is subjected to the action of a high-frequency electromagnetic field, a process with a significant heat release occurs in it due to the phenomenon of dielectric polarization, which makes a stimulating effect on the seed during its treatment (Cuglenok et al., 2003). The seed moisture helps to increase the level of selective absorption of moisture by the seeds proper and by the parasitic microorganisms that are inside the seed; these microorganisms have stronger absorption capacity and they absorb the moisture flowing along the capillaries dozen times more rapidly than the intracellular seed structures. At the same time they swell, their humidity reaches 80–90 %, while the moisture content in the seeds does not increase, but remains at the previous level. The electromagnetic processing of such seeds selectively warms the moistened microorganisms, because due to the high heating rate, the temperature of any biological object, regardless of its size, increases in proportion to its humidity (Cuglenok, 2003). According to the basic idea of seed disinfection with the energy of HF and EHF fields, the properties of the seeds and parasitic phyto-pathogens are separated when moistening them (Cuglenok, 2003).

The pre-sowing treatment of wheat seeds with EHF has provided an increase in the yield capacity by 23 % and at the same time the seeds were completely rendered the sanitary from the fusariosis infection in comparison with the control (the untreated seeds) and standard (the seeds treated with the fungicides). When treating the barley seed there is three times reduction in the leaf-blight helminthosporiosis infection in comparison with the control (Cuglenok et al., 2003).

The combination of the ultrasonic seed treatment at the initial stage and subsequent treatment with EMF of EHF increases the humidity, germinating power and sprouting energy due to the ultrasound; it also reduces the infestation and stimulates the seed growth quality due to EMF of EHF. The use of this method of treatment allows refusing the use of the chemicals harmful both to the environment and human beings (Zubova, 2013).

Formation of yield and quality of winter wheat and spring barley under different methods of pre-sowing seed treatment

Increasing the productivity of cereal crops and obtaining environmentally friendly products requires the improvement of the cultivation technology, especially in the system of plant protection against the harmful components of agrocenosis (Popov et al., 2014). The pre-sowing seed treatment helps to reduce the negative impact of trauma, improves the yielding properties of seeds through the application of physical, chemical, biological and other measures to disinfect, improve the germination and increase the productivity. In the existing plant protection system the methods of the pre-sowing seed treatment by nature of influence are divided into the following basic methods: chemical, biological and physical ones.

The winter cereal crops treatment provides not only the effective protection of seeds, seedlings, and shoots from the infections, but also improves the hibernation of plants in the conditions of the unfavourable autumn and winter periods. The disinfection of seeds makes it possible to preserve up to 12 % of the grain yield of winter cereal crops, up to 15 % of spring barley at the crop yield capacity of 4.0–5.0 t/ha (Smetanko, 2017). Nowadays the seed treatment with the preparations of not only fungicidal but also insecticidal action is becoming more widespread (Gorban, 2013).

According to the data of the Central Scientific and Research and Project and Technological Institute of Livestock Mechanization and Electrification the effect of the ultraviolet irradiation (UVI) provides the increase in the cereal crops yield by 10–12 % and an increase in the protein content of the green mass of corn by 6–10 %; sugar content increases by 12–16 %. The efficiency of this method of the pre-sowing seed treatment is confirmed by testing at the seed research stations (Savelev, 1981). The short-term and repeated short-term treatments of seeds with the focused wave of UVI raise the yield capacity of cereal crops up to 10–15 % (Vladykin, 1999). The mass use of the growth regulators became possible only after the creation of the preparations based on the analogues of the natural substances. The literature sources indicate that there are the preparations with the application rates of dozens of grams or milligrams per ton of seeds or hectare of crops (Vladykin, 1999).

The technology of the pre-sowing seed treatment with the growth regulators has its positive peculiarities. The preparations accelerate the development of the root system at the initial stages of development and such processing can be carried out in advance together with the treatment and coat-forming agents at the seed factories or on the farms (Merkushina, 1994). As a result of the growth regulators action the mass of the root system increases to 57 % due to the greater number of the secondary roots of the cereal crops; the number of spikelets in the ear and the mass of 1000 grains also increase. The increase in the yield capacity of winter wheat amounts to 6–25 %, and the protein content in the grain is increased by 0,5–1,7 % (Merkushina, 1994).

O. Holovko found out that the use of the plant growth regulators enables to directly regulate the most important processes in the plant organism, to fully implement the potential possibilities of the variety inherited in the genome by nature and selection (Golovko, 1997). It was possible to achieve an increase in the agricultural production by 15–20 % or more by using a number of the growth regulators in several countries (Marenich, 2011). V.Yu. Sudenko notices that most preparations for the pre-sowing seed treatment have no mechanisms influencing the seed sprouting, shoots formation, density of the crops, and formation of the vegetative and reproductive organs of the plants (Sudenko, 2016).

According to the researches carried out by M.M. Marenych the positive influence of the preparations effecting the growth, stimulating the seed germination of winter crops and protecting the seedlings from the stress caused by the lack of moisture has been noted (Marenich, 2011). A.O. Shevchenko testifies that when using the pre-sowing application of biological stimulants, the field germinating power of winter wheat seed increases by 5 % on the average (Shevchenko & Anishin, 1997). According to A.S. Merkushyna the effect of all phyto-regulators depends on their concentration; at the same time the increased concentration causes a sharp slowing-down of growth and death of the plants (Merkushina, 1999). L.A. Anishyn notes that the wheat seed treatment with the winter growth regulator Emistim C significantly increases the processes of respiration, nutrition and photosynthesis and increases the accumulation of chlorophyll in the leaves (Anishin, 1999). In the CAE "Ukraine" of the Buchansk district in the Ternopil region, as well as on a number of other farms, the yield capacity of winter wheat increased by 0,5–0,6 t/ha when applying Emistim C (Anishin, 1999). At the same time it was found out that the rate of the treatment agents can be reduced by 25–30 % by combining the treatment of winter wheat seeds with the plant growth regulator Emistim C without reducing their protective effect, and this method can save money. The seed treatment with the growth regulators also significantly improves the baking quality of winter wheat grain (Anishin, 1999).

According to L.Yu. Kerefov when treated the winter wheat seeds with Emistim C at a rate of 10 ml/t, there was an increase in the yield by 0.36 t/ha, and treating with Agrostimulin at the same rate gave an increase by 0.44 t/ha at the yield capacity under the control of 0.49 t/ha (Kerefova, 2004). The pre-sowing seed incrustation with a tank mixture consisting of a coat-forming agent, a growth regulator and a treatment agent under modern technologies of cereal crops cultivation is a very important element of technology that contributes to increasing the resistance of plants to stress weather conditions, and as a result, to an increase in the productivity (Bezpal'ko et al., 2019). In the conditions of the unstable moistening of the Northern Steppe, the use of the plant growth regulators to treat the spring chaffy barley seeds before sowing helped to increase the crop productivity by 0.12–0.54 t/ha (3.1–13.8 %) (Sudenko, 2016).

According to the researches of S.P. Ponomarenko the high efficiency of the growth regulators is stipulated by the content of a balanced complex of the biological substances, which accelerates the growth of the green mass and the root system, and therefore the nutrients are more actively used, as a result of which the resistance to the diseases, stresses and unfavourable weather conditions increases (Ponomareno, 1998).

O.V. Smetanko notes that the use of the biological preparations based on the microorganisms *Bacillus polymyxa, Enterobacter nimipressuralis, Aehromopacter album* have a positive influence on the quality indices of winter wheat grain. Thus, against the background of nitrogen mineral fertilizer application when using the preparation based on *Bacillus polymyxa*, a mathematically significant increase in the gluten content was observed (Smetanko., 2007). According to the researches of L.O. Chaikovska it is recommended to carry out the pre-sowing bacterization of winter wheat and spring barley seeds using the biological preparations that increase the protein and gluten content in the grain. When using Polymixobacterin, Albobacterin and Phosphoenterin the protein content amounted to 13.7 %, 13.2 % and 12.,5 % (under the control it was 9.9 %), the gluten content amounted to 31.7 %, 30.0 % and 28.0 % (under the control it was 19.2 %) (Bingham & Topp, 2009).

The most promising element of the modern technologies for growing winter wheat and spring barley is the pre-sowing seed treatment with the biological preparations that stimulate the germination, protect the seeds from the diseases, and eliminate the environmental pollution.

Development of ecological methods for increasing efficiency of pre-sowing treatment of cereal crop seeds and problems that need to be solved

Recently, due to the excessive pollution of the environment as a result of the widespread uncontrolled use of pesticides and mineral fertilizers it is very important to look for the alternative farming systems. They are based on biologization, which implies a restriction, and in the long term the refusal from using the chemicals, and the wide use of new methods of biological plant protection, especially under the unfavourable environmental conditions (Kindruk & Gavrilyuk, 2007).

In the researches of the Plant Production Institute named after V.Ya. Yuryev of NAAS and other research institutions of Ukraine the influence of different methods of the pre-sowing seed treatment, including the use of the plant growth regulators, biological preparations, seed incrustation, ozonization, physical methods of treatment and their combination in comparison with the chemical disinfector on the formation of the yield capacity and quality indices of many agricultural crops has been studied for many years (Krasilovec, 2014).

The intensive use of chemicals for the pre-sowing seed treatment while increasing the plants productivity inevitably causes a number of the undesirable effects of the environmental and economic characters. The environmental effects of applying pesticide are strengthened by their cumulative effect, which is very dangerous for the quality of the products obtained. These substances are not natural and therefore cause the carcinogenic and mutagenic effects. At the same time the seed disinfection is an obligatory agro-technical measure in the technology of crops cultivation, without which the problem of increasing their yield capacity cannot be solved. Therefore, the scientists and practitioners in several countries of the world are passing on to the alternative methods of the pre-sowing seed treatment (Krasilovec, 2014).

One of the most environmentally friendly methods of the pre-sowing seed treatment is the irradiation with microwave field (MWF) of extra high frequencies (EHF). The rates of chemicals in the agro-systems are significantly reduced with the development of the organic agricultural production in Ukraine. Since 2004 the EU has forbidden the use of the traditional methods for the chemical seed treatment in organic farming. This led to the search for the new methods of the pre-sowing seed treatment, primarily the physical ones as an alternative to the chemical methods (Drincha & Cydendorzhiev, 2010). However, the physical methods (high frequency, microwave and warm air or water treatment) compared with chemical disinfection do not influence the diseases communicated to the plants through the soil organisms. The methods of the physical seeds treatment that can be used in practice include the long-known method of heat treating. The seeds are heated with water, steam or air. The main criterion for this is the combination of the temperature factor (critical for the pests and seeds). The main disadvantage of this method is the high water content in the seeds after treatment, which leads to significant energy consumption necessary for drying the seeds (Presman, 1956).

In recent years the methods using the electromagnetic field (EMF) of extra high frequency (EHF) range in the food industry (microwave ovens) and for the drying of food and agricultural products have become widespread. The use of high-frequency electromagnetic waves in the microwave range for the seed treatment is characterised by a high intensity of heating, as well as the penetration of heat into the inner tissues of the grain (Presman, 1956). The probability to reduce its sprouting increases significantly. This method is of little use in practice because when drying the surface of the seed, the pathogenic organisms die together with the seed. Yet in 1956 the scientist A.S. Pressman proposed the action of the electric waves not only as the thermal energy but also as the processes taking place against the background of heating (Presman, 1958). He made an assumption about the information influence of the electromagnetic field (EMF) on the biological objects.

At the present stage the possible mechanisms of EMF influence on the plant organisms are relatively divided into several levels (Kalinin, 2002). Firstly, it is the energy influence that has the physical and mechanical basis of the thermal effect (temperature rise, and local pressure) and is the most studied. The most uncertain level is the information one, when the flow of the external energy can not make significant changes in the thermodynamics of the biological processes, but can affect the processes of vital activity of the plant organisms. This approach is implemented at the cellular level and is linked to the biological structures. These are the elements of cell membranes that have a significant dipole electric moment (protein and enzymes molecules, etc.) (Kalinin, 2002).

Today it is the information component that has a great scientific interest for both the physicists and biologists. The most promising among all physical methods of the pre-sowing seed treatment is the microwave (MW) technology; it is the result of many years of the researches of the scientists of the military and industrial complex and the branch science (Shevchenko, 1999). Many years of the scientific experiments and experience of a number of the agricultural producers confirm that the microwave field suppresses the whole complex of seed infection, which creates an alternative to the chemical method of plant protection (Paramonov, 2013).

The use of the microwave complexes for seed stimulation by the specialists of the leading scientific and research institutions, both in Ukraine and abroad, made it possible to identify the reserves for increasing the yield capacity of the agricultural crops. According to the results of a number of authors, the attention to the physical method of the pre-sowing seed treatment with a microwave field is explained by the fact that a number of technological and economic issues can be solved (Hajdeker, 1982). The main ones are an increase in the laboratory and field germination of the seeds, the accelerated plant development and ripening, resistance to the frost, drought, pests and pathogens, increase in the biomass, improvement of the production quality (starch, protein, etc.), disinfection of seeds and obtaining the environmentally friendly products with the reduced nitrate and pesticide content. But the main thing is that the researches connected with testing MW seed stimulation technology occupy a special place in the problem of the significant increase in the yield capacity of the field crops (Peresypkin, 1989), that is, they are used in order to increase the realization level of the plant productivity potential (Kindruk & Gavrilyuk, 2007).

The results of the researches carried out at the Selection and Genetic Institute of NAAS indicate that when treated the elite seeds of three varieties of soft winter wheat with MW field, the laboratory germination has increased by 2–3 % at the initial indices of 95–96 %. The field germination has exceeded the control by 10–12%, and the crop capacity, depending on the variety, was exceeded by 12.1–33.6 %. The efficiency of MW treatment of wheat seeds has been confirmed in the researches at the genetic level (Kindruk & Gavrilyuk, 2007). The new technology of the pre-sowing seed treatment of winter cereal crops was tested under very severe Ukrainian conditions in the winter of 2002–2003, when winter crops were destroyed by frosts over a large area. According to the data of the Vinnytsia Research Station, the seeds of winter wheat of Donetska 48 variety, treated with MW field not only overwintered, but also yielded 2.5 t/ha, while under the control (the seeds without treatment) the plants died.

It is known that among the methods that stimulate the growth processes and accelerate the growth and development of plants are the physical, chemical and biological ones. According to the authors none of them has been used widely because they are insufficiently substantiated; the mechanisms of their action and aftereffect on the seeds have not been disclosed (Shevchenko et al., 2007).
The effect of the biological stimulation of seeds with the energy of the microwave field is manifested in different ways depending on the genotype of the plants, variety reaction, as well as the initial quality of seeds. According to the data of the researches carried out with winter cereal crops (wheat, and barley) this effect is leveled by the conditions of autumn and winter period, but even in such years the increase in the yield was mostly reliable (Timoshenko, Homenko, Vokogon & Tuchnij, 2009). The spring cereal crops have a better effect from MW seed stimulation than the winter cereals, which is explained by more favourable conditions and a short growing season of the crops, when the energy of MW field has a greater aftereffect on the plant (Kalinin, 2002). The arid summer conditions of the southern Ukraine are especially vulnerable for the spring cereal crops. The researches of the scientists of the Odessa Agrarian University carried out during the very hot summer of 2003 show that the yield capacity of nine varieties of spring barley obtained from the seeds treated with MW field exceeded the control crops by 0.3–0.5 t/ha with an average yield capacity of 0,83 t/ha as a result of the drought (Presman, 1956).
The authors investigated the possible mechanisms of MWF action on the biological objects at the functional level, the third after the energy and information ones (Kalinin, 2002). The optimum EMF modes that activate the action of the enzyme systems of the agricultural crops seeds have been identified; at the same time the structural and functional integrity and biochemical composition of the treated seeds have not been damaged. During the vegetation period the intensity of assimilation processes has increased. According to the authors the universal character and practical importance of the MW technology consist in the fact that along with the increase in the yield capacity of field crops, the technogenic load on the environment is reduced. The technology minimizes, and sometimes completely eliminates the application of toxic chemicals, among which the pesticides are especially dangerous. Their decomposition in the soil, plants and water is often accompanied by more stable and toxic elements in comparison with the initial compounds (Tehnologiya mikrohvilovoyi obrobki…, 2003). The obtained data and the gained experience of using different modes of EMF have been widely tested in the laboratory conditions and at the experimental plots of different farms and are recommended to be used in the agricultural practice of the pre-sowing seed treatment.
At present the producers and various design offices propose a large number of installations for the pre-sowing seed treatment of the agricultural crops, as well as for drying seeds and other loose materials (Chmil & Lazaryuk, 2016). For example, the company "Vozrozhdeniie" (Odessa) has developed the equipment for the pre-sowing seed treatment "Microsteam–2M" (Figure 1).

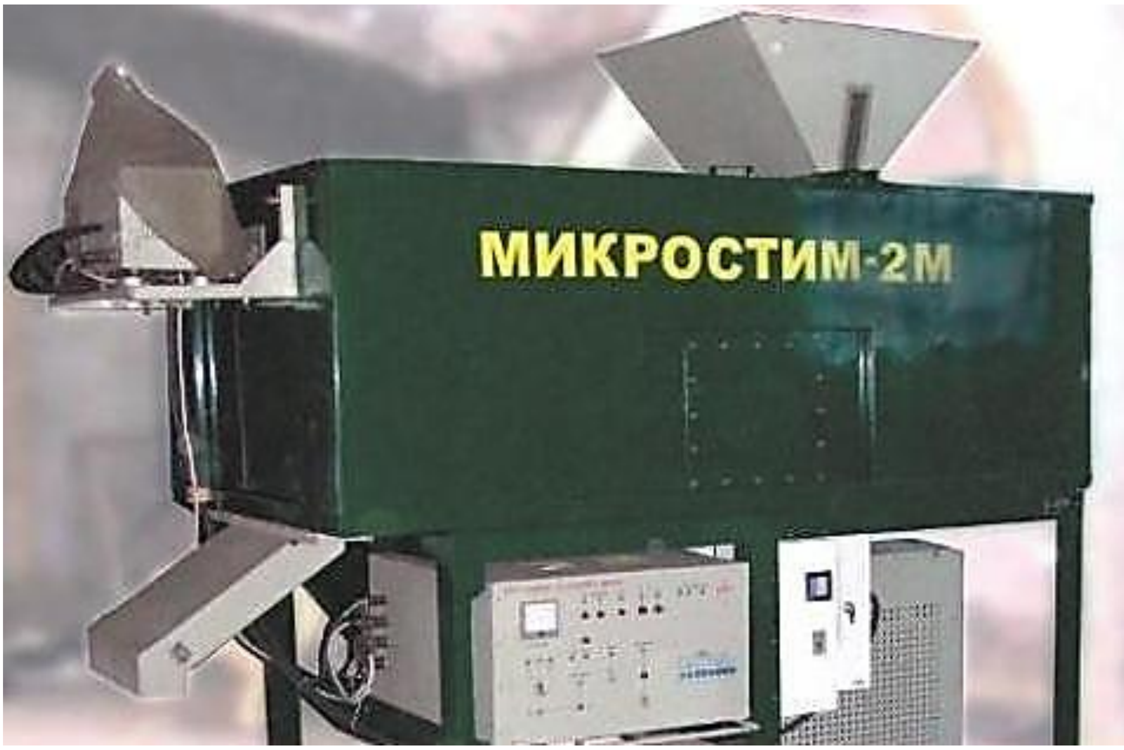

Fig. 1. Microwave installation "Microsteam-2M"

The limited partnership "Energopolis" (Dnipro) has developed the installation AST-3 (Figure 2).
A microwave installation has also been proposed in Kharkiv by the limited partnership "AVIRON EHF Technology" (Figure 3), which has a well-developed technical and scientific base for mass production of the installation and its key elements.

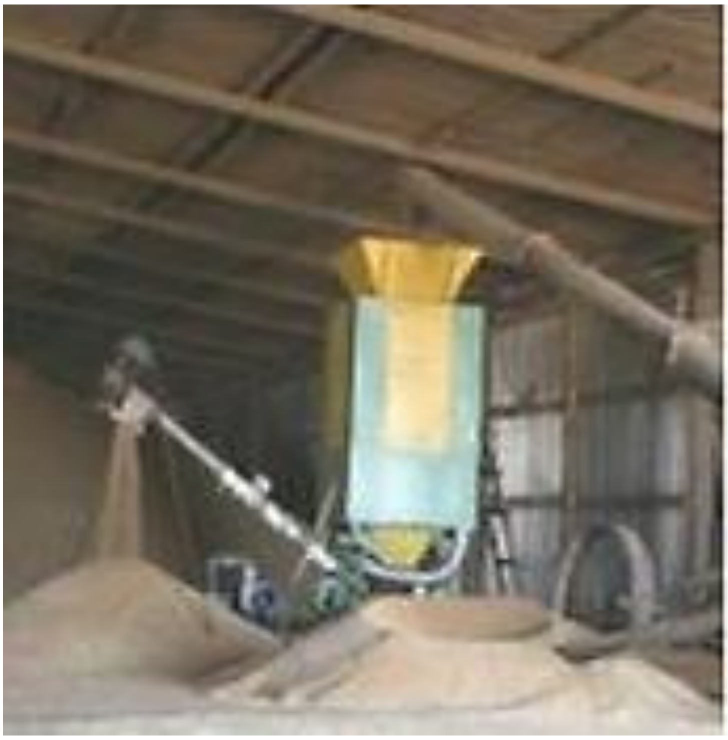

Fig. 2. Microwave installation "AST-3"

Several types of the microwave installations (Figure 4) for the pre-sowing seed treatment of the agricultural crops on the basis of the microwave modules have been developed at the Belarus State University (Babich et al., 1994). The parameters of the irradiation module are selected individually for each crop.

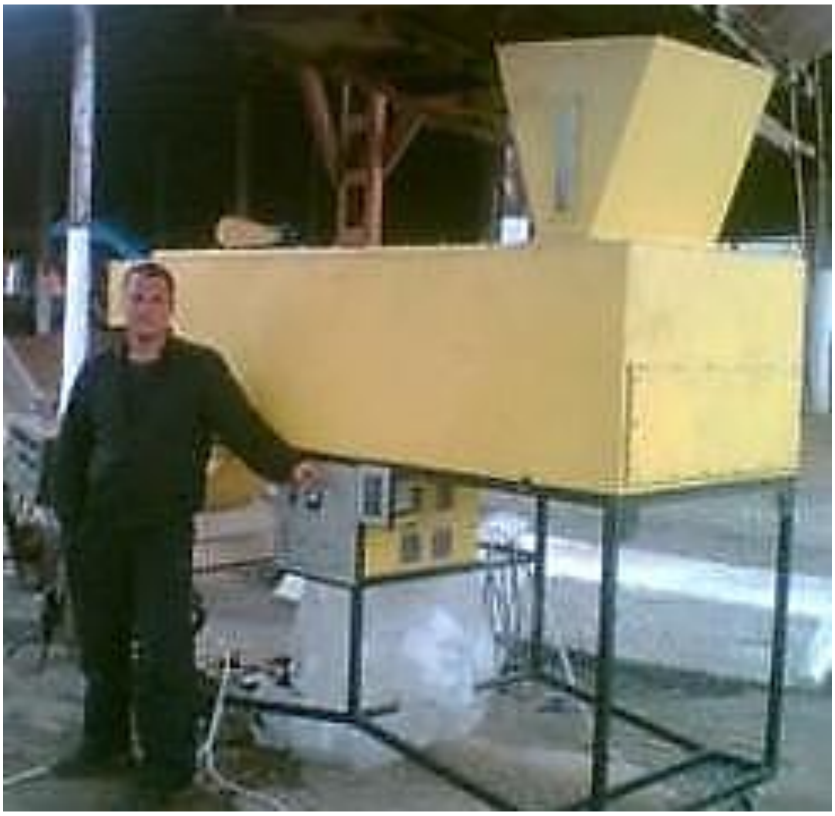

Fig. 3. Microwave installation AVIRON

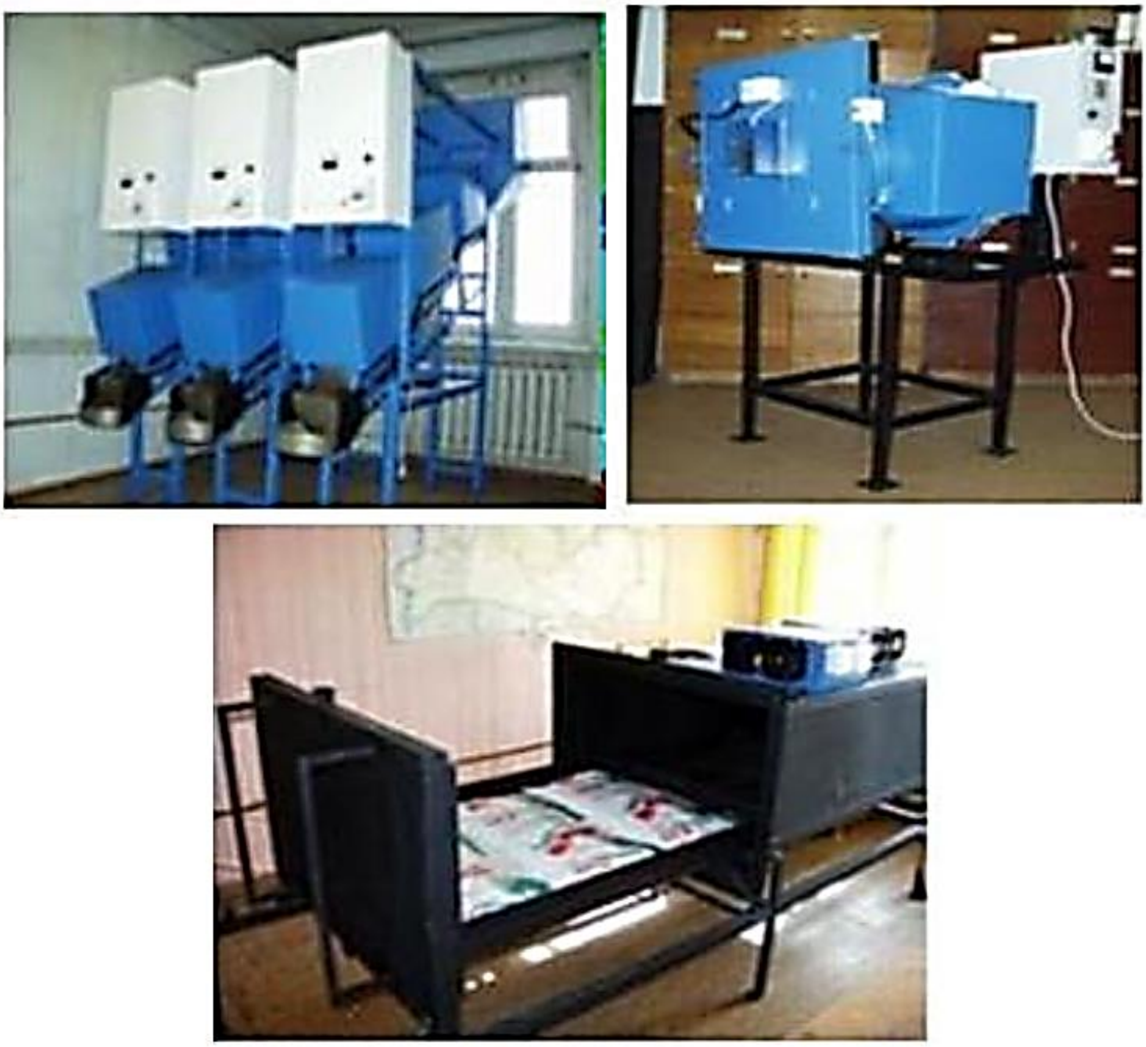

Fig. 4. Installations for pre-sowing seed treatment, drying and disinfection with MWF of EHF

The biological preparations based on the beneficial microorganisms along with the physical methods for the seed treatment with the microwaves are becoming widespread in the agricultural practice (Chmil & Lazaryuk, 2016).

The researches of the recent years testify that among the new nontraditional reserves for increasing the productivity of the cereal spike crops that do not require the significant extra costs there is a widespread introduction of the plant growth regulators of a new generation (Kalinina & Ronzhina, 2010). The order of the Ministry of APC and UAAS №330/113 "On the Introduction of New Growth Regulators" dated 18.10.1999 emphasise that the Ukrainian preparations are the highly profitable reserves for increasing the yield capacity, especially in the conditions of the insufficient supply of soil with the nutrients and since 20000 it has been recommended to the specialists of the farms to apply the new growth regulators as an obligatory agricultural measure (Rekomendaciyi…., 2005).

The growth regulators at very small rates help to accelerate the growth and development, increase the productivity and improve the quality of the agricultural plant products. Penetrating into the plants, they are involved in the metabolism, activate the biochemical processes, and increase the level of the plant vital activity. The regulators influence the system of hormonal regulation, which determines the nature of the most important physiological processes, in particular, accelerates the formation of new plant organs and the beginning of flowering and ripening (Bespalko & Buryak, 2014)

On the experimental winter wheat crops of the Chernihiv Agricultural Station the number of the productive stems increased by 16,1–17,1 % under the influence of the biological stimulants (Kosolap, 2008). In the nearest future the combination of the microwave technology with the subsequent seed treatment with the plant growth regulators should become a perspective direction of science and practical agriculture since it gives the possibility to solve a number of problems of the agricultural production in a complex.

Conclusions

The increase in the cereal spike crops yield capacity under the current change of the climatic conditions in Ukraine will have a positive tendency in the nearest future, but the sustainable grain production under sharp weather fluctuations is possible only with the improvement of the agro-technological systems. The pre-sowing seed treatment with chemical synthesis pesticides remains the main method in the agricultural industry today. However, the pesticides inevitably have a negative influence on the ecosystem of any level.

A more environmentally friendly method of seed treatment under the intensive technology is the combination of the microwave seed irradiation and seed incrustation with the plant growth regulators that provide an increase in the cereal crops yield capacity up to 15–20%.
It is possible to reduce the negative influence of chemical measures on the quality of the cereal crops seeds by using for the seed treatment a mixture of a treatment agent with the preparations having the stimulating properties. The most promising among all physical methods of the pre-sowing seed treatment is the microwave technology which suppresses the entire complex of the seed infection and can become an alternative to the chemical method of plant protection.
The universal character and practical importance of MW technologies in combination with the growth regulating substances consist not only in the increase in the yield capacity of the field crops, but also in reducing the technogenic load on the environment. The peculiarity of EMF of EHF application in the agricultural production is the necessity to take into account the specific electro-physical, technological and biological properties of the crops, which high heterogeneity greatly influences the action of the electromagnetic energy and the final result.

References

Adamenko, T.I. (2008). Perspektivy ukrainskogo zernovogo rynka v kontekste globalnogo potepleniya. Hranenie i pererabotka zerna, 6 (108), 28–32 (in Russian).

Anbessa, Y., Juskiw, P., Good, A., Nyachiro J. & Helm J. (2009). Genetic variability in nitrogen use efficiency of spring barley. Crop Sci., 49, 1259–1269.

Anishin, L. (2002). Regulyatori rostu roslin: sumnivi i fakti. Propoziciya, 5, 64–65. (in Ukrainian).

Anishin, L.A. (1999). Biostimulyatori dlya ozimoyi pshenici. Silskij chas. 3.09, 10 (in Ukrainian).

Anishin, L.A. (1999). Vpliv biostimulyatoriv na vrozhaj i yakist ozimoyi pshenici. Novini zahistu roslin, 7/9, 29–30 (in Ukrainian).

Avramenko S. (2016). Elementi udobrennya yachmenyu yarogo. Propoziciya, 3, 82–87 (in Ukrainian).

Babayanc, O.V. (2014). Zastosuvannya preparativ novogo pokolinnya u virobnictvi zernovih kolosovih kultur. Nasinnictvo, 2, 2 (in Ukrainian).

Babich, A.O., Himich, V.V. & Poberezhna, A.A. (1994). Svitove virobnictvo zerna prodovolchih i furazhnih kultur. Kormi i kormovij bilok: materiali pershoyi vseukrayinskoyi mizhnarodnoyi konferenciyi (16–17.11), Vinnicya, 74–75 (in Ukrainian).

Batalova, T.S. (1989). Zashita zernovyh kultur ot golovnevyh zabolevanij i kornevyh gnilej: rekomendacii, Moskva, Agropromizdat, 64 (in Russian).

Belaev, A.D., Lavrushko, N.I. & Alekseenko, V.M. (1985). Izmenenie elementov plodorodiya chernozyoma tipichnogo pri pochvozashitnyh tehnologiyah. Povyshenie Effektivnosti ispolzovaniya udobrenij i plodorodiya pochv v Ukr. SSR: tez. dokladov konferencii. Harkov (in Russian).

Bespalko, V.V. & Buryak, Yu.I. (2014). Vliyanie predposevnoj obrabotki semyan mikrovolnovym polem v sochetanii s regulyatorom rosta i biopreparatom na posevnye kachestva i urozhajne svojstva yachmenya yarovogo. Zernobobovye i krupyanye kultury: nauchno-proizvodstvennyj zhurnal, 4, 133–139 (in Russian).

Bezpalko, V.V. (2016). Formuvannya urozhajnosti pshenici ozimoyi pri zastosuvanni ekologichno bezpechnih sposobiv peredposivnoyi obrobki nasinnya. Visnik Centru naukovogo zabezpechennya APV Harkivskoyi oblasti. Harkiv, 21, 11–17 (in Ukrainian).

Bezpal'ko, V.V., Zhukova, L.V., Stankevych, S.V. & Zabrodina I.V. (2020). Ways to increase the yield capacity of winter wheat and spring barley on the basis of applying pre-sowing seed irradiation with extra high frequencies microwave field in the conditions of eastern forest-steppe of Ukraine: monograph. Kharkiv, PublishingHouse I. Ivanchenko, 201.

Bezpal'ko, V.V., Zhukova, L.V., Stankevych, S.V., Ogurtsov, Yu.H., Klymenko, I.I., Hutians'kyi, R.A., Fesenko, A.M., Turenko, V.P., Zabrodina, I.V., Bondarenko, S.V., Batova, O.M., Golovan, L.V., Klymenko, I.V., Poedinceva, A.A., Melenti, V.O. (2019). Ecologically safe methods for presowing treatment of cereal seeds. Ukrainian Journal of Ecology, 9(3), 189–197.

Bezpal'ko, V.V., Zhukova, L.V., Stankevych, S.V., Ogurtsov, Yu.H., Klymenko, I.I., Hutians'kyi, R.A., Fesenko, A.M., Turenko, V.P., Zabrodina, I.V., Bondarenko, S.V., Batova, O.M., Golovan, L.V., Klymenko, I.V., Poedinceva, A.A., Melenti, V.O. (2019). Ecologically safe methods for presowing treatment of cereal seeds. Ukrainian Journal of Ecology, 9(3), 189–197.

Bingham, I. J. & Topp, C. F. E. (2009). Potential contribution of selected canopy traits to the tolerance of foliar disease by spring barley. Plant Pathology, 58, 1010–1020.

Bojko, P. & Kovalenko, N. (2007). Potencialnaya produktivnost zernovyh kultur v sevooborotah. Zerno, 4, 20–23 (in Russian).

Chmil, A.I. & Lazaryuk, K.O. (2016). Analiz suchasnih nvch-ustanovok dlya peredposivnoyi obrobki nasinnya silskogospodarskih kultur. Energetika i avtomatika, 2, 156–163 (in Ukrainian).

Cuglenok, G.I. (2003). Sistema issledovaniya elektrotehno-logicheskih processov VCh- i SVCh- obrabotki semyan. Thesis of Doctoral Dissertation. Krasnoyarsk (in Russian).

Cuglenok, N.V., Cuglenok, G.I. & Halanskaya, A.P. (2003). Sistema zashity zernovyh i zernobobovyh kultur ot semennyh infekcij. Krasnoyarsk, Izd-vo KrasGAU (in Russian).

Derecha, O.A. & Dazhuk, M.A. (1997). Alternativna sistema zahistu – vazhlivij zasib upravlinnya agrobiocenozom pshenici ozimoyi. Visnik agrarnoyi nauki. Specialnij vipusk, 56–58 (in Ukrainian).

Dindorogo, V.G. & Strona, I.G. (1989). Inkrustirovanie semyan polevyh kultur i perspektivy ego vnedreniya v proizvodstvo. Teor. i prakt. pred. obrabotki semyan. Kiev (in Russian).

Drincha V.M., Cydendorzhiev B.D. & Kubeev E. (2010). Osnovnye principy predposevnogo himicheskogo protravlevaniya i fizicheskogo obezzarazhivaniya semyan. Hranenie i pererabotka zerna, 12(158), 20–22.

Dubrov, A.P. (1963). Dejstvie ultrafioletovoj radiacii na rasteniya. Moskva, Izd–vo AN SSSR, 124 (in Russian).

Fokin, A. (2009). Protruyennya nasinnya: istoriya ta suchasnij asortiment. Propoziciya, 2, 8–10 (in Ukrainian).

Fyodorova, N.A., Garmashov, V.N., Kostromitin, V.M. & Musatov, A.G. (2020). Sortovaya agrotehnika zernovyh kultur: monografiya. Kiev. Urozhaj (in Russian).

Gentosh, D.T., Kyryk, M.M., Gentosh, I.D., Pikovskyi, MY., Polozhenets, V.M., Stankevych, S.V., Nemerytska, L.V., Zhuravska, I.A., Zabrodina, I.V., Zhukova, L.V. (2020). Species compositions of root rot agents of spring barley. Ukrainian Journal of Ecology, 10 (3), 106–109.

Golovko, O. (1997). Visokij vrozhaj zavdyaki vitchiznyanim biostimulyatoram. Uryadovij kur'yer, 22.02, 9. (in Ukrainian).

Gorban, G.S. (2013). Protruyuvannya nasinnya – osnovnij zahid dlya kontrolyu hvorob. Propoziciya, 9, 78–81 (in Ukrainian).

Gorban, R. (2013). Vdale protruyuvannya – proste rishennya rozkrittya potencialu kulturi. Agronom, 1, 102–103 (in Ukrainian).

Gulidova, V.A. (2001). Optimizaciya obrabotki pochvy pod yarovoj yachmen. Zemledelie, 6, 18–19 (in Russian).

Hajdeker, U. (1982). Fiziologiya i biohimiya prorostaniya semyan. Moskva, Kolos, 312 (in Russian).

Hasanov, E.R., Kamaletdinov, R.R. & Hajrullin, R.M. (2010). Obezzarazhivanie i stimulyaciya prorastaniya semyan tokami SVCh. Mehanizaciya i elektrifikaciya selskogo hozyajstva, 3, 14–15 (in Russian).

Horiainova, V.V., Turenko, V.P., Bilyk, M.O., Stankevych, S.V., Zhukova, L.V., Batova, O.M., Martynenko, V.I., Kucherenko, Ye.Yu., Zviahintseva, A.M. (2020). Species composition, morphological and biological peculiarities of leaf pathogens of spring wheat. Ukrainian Journal of Ecology, 10(3), 115–120.

Kalinin, L.G. (2002). Kompleks rabot po issledovaniyu vliyaniya MV na processy biostimulyacii kultur. Hranenie i pererabotka zerna, 3, 31–34 (in Russian).

Kalinin, L.G. (2002). Rezultaty povysheniya urozhajnosti polevih kultur pri obrabotke semyan mikrovolnovym polem. Hranenie i pererabotka zerna, 1, 28–31 (in Russian).

Kalinina, E.A. & Ronzhina, E.S. (2010). Dejstvie citokinina na rost, fotosintez i dyhanie kak sostavlyayushie produkcionnogo processa u rastenij kukuruzy *Zea mays* L. Fiziologo-biohimicheskie osnovy produkcionnogo processa u kultiviruemyh rastenij: materialy dokladov vserossijskogo simpoziuma s mezhdunarodnym uchastiem. Saratov, Saratovskij istochnik, 36–38 (in Russian).

Kerefova, L.Yu. (2004). Pro vpliv regulyatoriv rostu na yakisni pokazniki zerna ozimoyi pshenici. Zernovoe hozyajstvo, 4, 4–5 (in Ukrainian).

Kindruk, M.O. & Gavrilyuk, M.M. (2007). Mikrohvilova stimulyaciya nasinnya: problemi ta perspektivi yiyi zastosuvannya. Mikrovolnovye tehnologi v narodnom hozyajstve, 6, 36–38. (in Ukrainian).

Kirichenko, V.V. (2009). Ozonova tehnologiya peredposivnoyi obrobki nasinnya silskogospodarskih kultur. Posibnik ukrayinskogo hliboroba. Harkiv, 128–131 (in Ukrainian).

Kirichenko, V.V., Kostromitin, V.M. & Korchinskij, A.A. (2002). Formuvannya sortovoyi strukturi zernovih kolosovih kultur za agroekologichnim principom. Visnik agrarnoyi nauki, 4, 26–28 (in Ukrainian).

Kisel, V.I. (1997). Biologichne zemlerobstvo: tendenciyi v sviti ta poziciya Ukrayini. Zemlerobstvo, gruntoznavstvo, agrohimiya, 10, 9–13 (in Ukrainian).

Kosolap, N.P. (2008). Allelopatiya – prichina mnogih posledstvij. Zerno, 9, 46–51 (in Russian).

Krasilovec, Yu.G. (2014). Efektivnist vitavaksu 200 FF na posivah pshenici ozimoyi ta yachmenyu yarogo v umovah shidnoyi chastini Lisostepu Ukrayini. Agro Elita: vseukrayinskij agrarnij zhurnal, 1(12), 26 (in Ukrainian).

Kratzsch, G., Wicke, H. & Ackermann, D. (1977). Standort und sortenspezifische Aubauempfehlungen fur eine effektive produktion von Brau – und Futtergerste. Feldwirschaft, 1, 14–17.

Kravchenko, M.S., Kravchenko, A.M., Masik, I.M. & Gupal, N.Ye. (2004). Efektivnist sposobiv osnovnogo obrobitku gruntu v posivah yachmenyu v Lisostepovij zoni Sumskoyi Oblasti. Visnik SNAU, 1(8), 114–119.

Lebed, Ye.M., Andrusenko, I.I. & Pabat, I.A. (1992). Sivozmini pri intensivnomu zemlerobstvi: monografiya. Kiyiv. Urozhaj (in Ukrainian).

Leus, N.F. & Kolomijchuk, S.G. (2009). Effektivnost primenenie mikrovolnovoj tehnologii v agropromyshlennom komplekse. Mikrovolnovye tehnologii v narodnom hozyajstve, 7/8, 86–88 (in Russian).

Lihochvor, V. (2006). Primenenie azotnyh udobrenij na posevah ozimoj pshenicy. Zerno, 4, 18–20 (in Russian).

Lihochvor, V.V. & Petrichenko, V.F. (2006). Suchasni intensivni tehnologiyi viroshuvannya osnovnih polovih kultur. Roslinnictvo, Lviv, NVF Ukrayinski tehnologiyi, 105–107 (in Ukrainian).

Lihochvor, V.V. (1993). Resursozberezhennya pri viroshuvanni pshenici ozimoyi za intensivnoyu tehnologiyeyu. Vrozhajnist silskogospodarskih kultur, yakist produkciyi ta zmini vlastivostej gruntu pid diyeyu dobriv: zb. nauk. pr. Lviv. s.-g. in-t, 86–88 (in Ukrainian).

Lisovyj, M.P. (1999). Dovidnik iz zahistu roslin. Kiyiv. Urozhaj (in Ukrainian).

Marenich, M.M. (2011). Vpliv peredposivnoyi obrobki nasinnya ta mineralnogo zhivlennya na formuvannya elementiv strukturi vrozhajnosti pshenici m'yakoyi ozimoyi. Visnik Poltavskoyi derzhavnoyi agrarnoyi akademiyi,1, 169–172 (in Ukrainian).

Matveev, V.A., Golovnoj, A.M. & Severyanov, S.N. (2003). Energosberegayushaya obrabotka pochvy. Zemledelie, 2, 18 (in Russian).

Melnik, A.V. & Trocenko, V.I. (2008). Roslinnictvo z osnovami tehnologiyi pererobki. Praktikum: navchalnij posibnik. Sumi, VTD Universitetska kniga (in Ukrainian).

Merkushina, A.S. (1994). Fiziologo-biohimichni osnovi diyi giberelinu na roslini gorohu ta fitovagi. Biologo- ekologichni osnovi viroshuvannya silskogospodarskih kultur v umovah Lisostepu. Kiyiv, Silsgoposvita, 57–60 (in Ukrainian).

Merkushina, A.S. (1999). Fitoregulyatori ta mikroelementi v zahisti roslin. Visnik agrarnoyi nauki, Spec. vip., 54–57 (in Ukrainian).

Musatov, A.G., Galanickaya, O.I. & Pavlov, G.K. (1980). Vliyanie udobrenij na urozhaj i kachestvo zerna sortov yachmenya i ovsa v Stepi USSR. Ispolzovanie udobrenij pri intensivnyh tehnologiyah vozdelyvaniya selskohozyajstvennyh kultur. Dnepropetrovsk, 172 (in Russian).

Orel, S.Ye. & Bojko, P.I. (1987). Pravilna sivozmina – zaporuka visokogo vrozhayu. Kiyiv. Urozhaj (in Ukrainian).

Paramonov, K.Yu. (2013). Mikrohvilova pich zamist protrujnika. Parostok, 2, 7 (in Ukrainian).

Perelik pesticidiv i agrohimikativ, dozvolenih do vikoristannya v Ukrayini (2018). Kiyiv, Yunivest Media, 1065 (in Ukrainian).

Peresypkin, V.F. (1989). Selskohozyajstvennaya fitopatologiya. Moscow. Agropromizdat (in Russian).

Pikusha, G.R. & Bondarenko, V.I. (1985). Zernovi kulturi. Kiyiv, Urozhaj (in Ukrainian).

Ponomareno, S.P. (1999). Regulyatori rostu. Ekologichni aspekti zastosuvannya. Zahist roslin, 12, 15.

Popov, S.I. (2007). Naukove zabezpechennya efektivnogo provedennya kompleksu vesnyano-polovih robit 2007 roku v gospodarstvah Harkivskoyi oblasti: rekomendaciyi. Harkiv (in Ukrainian).

Popov, S.I. (2014). Naukove zabezpechennya efektivnogo provedennya kompleksu vesnyano-polovih robit 2014 roku v gospodarstvah Harkivskoyi oblasti: rekomendaciyi. Harkiv (in Ukrainian).

Presman A.S. (1958). Elektromagnitnye polya i zhivaya priroda. Moskva: Nauka,1958. S. 15. (in Russian).

Presman, A.S. (1956). O fiziologicheskih principah biologicheskogo dejstviya santimetrovyh voln. Uspehi sovremennoj biologii, 1, 10 (in Russian).

Prishepa, I.A. (1998). Primenenie smesi pesticidov i regulyatorov rosta na posevah zernovyh kolosovyh kultur. Agrohimiya, 8, 74–89 (in Russian).

Pushkina, N.V., Lyubeckij, N.V., Karpovich, V.A. & Rodionova, V.N. (2012). Modificirovannyj metod predposevnoj mikrovolnovoj obrabotki semyan. Novosti nauki i tehnologij, 2(21), 36–40 (in Russian).

Reddy, K. C., Soffes, A. R. & Prine, C.M. (1986). Tropical legumes for green manure Nitrogen production and the affects of succeeding crop yields. Agron J., 78, 1, 1–4.

Rekomendaciyi iz zastosuvannya visokoefektivnih regulyatoriv rostu roslin pri viroshuvanni kolosovih zernovih kultur (2005). Mizhvidomchij naukovo-tehnichnij centr Agrobioteh NAN ta MON Ukrayini. Kiyiv (in Ukrainian).

Retman, S. (1998). Protruyennya nasinnya – zaporuka uspihu. Novini zahistu roslin: shokvartalnij dodatok do zhurnalu Propoziciya, 12, 27–28 (in Ukrainian).

Sajko, V.F. (1997). Perspektiva virobnictva zerna v Ukrayini. Visnik agrarnoyi nauki, 9, 27–32 (in Ukrainian).

Sajko, V.F. (2008). Naukovi osnovi zemlerobstva v konteksti zmin klimatu. Visnik agrarnoyi nauki, 11, 5–10. (in Ukrainian).
Sajko, V.F., Gricaj, A.D., Gordecka, S.P. (1994). Ozimi zernovi kulturi. Naukovi osnovi vedennya zernovogo gospodarstva. Kiyiv. Urozhaj, 228–242 (in Ukrainian).
Samdelle, S.A. & Read, D.W. (1968). Influence of air temperature on the growth, yield and some growth analysis characteristics of Chinook wheat grown in the growth chamber. Canad. J. Plant Sci, 48, 3, 28–36.
Savelev, V.A. (1981). Fizicheskie sposoby obrabotki semyan i effektivnost ih ispolzovaniya. Sibirskij vestnik s-h. nauki, 5, 26–29 (in Russian).
Secnjak, I. & Kindruk, N.A. (1984). Ekologia nasion I okreslajace ja crynnsks. Bsnl. Inst. Hodowl.i Aklim. Rosl, 158, 267.
Sekun, M.P. et al., (2007). Dovidnik iz pesticidiv; za redakciyeyu profesora. Kiyiv. Kolobig (in Ukrainian).
Shamgunov, I.I. & Stepura, A.V. (2017). Issledovanie vliyaniya predposevnogo svch vozdejstviya na morfologicheskie pokazateli prorostayushih semyan yarovoj pshenicy. Inzhenernyj vesnik Dona, 2. Available from: ivdon.ru/ru/magazine/archive/n2y2017/4243 (in Russian).
Sherbakov, K.N. (2002). Stimulyaciya rostovyh processov rastenij nizkoenergeticheskim magnitnym polem. Mehanizaciya i elektrifikaciya selskogo hozyajstva, 7, 26–29 (in Russian).
Sherbakov, V.M. (1998). Intensivnye tehnologii i ih potencial. Dostizheniya nauki i tehniki APK, 5, 12–14. (in Russian).
Shevchenko, A. & Anishin, L. (1997). Rezerv pshenichnoyi nivi. Biostimulyatori rostu novogo pokolinnya. Zahist roslin, 10, 21 (in Ukrainian).
Shevchenko, A.M. (2007). Znachenie mikrovolnovoj tehnologii v narodnom hozyajstve. Mikrovolnovye tehnologii v narodnom hozyajstve, Odessa, 8–9. (in Russian).
Shevchenko, A.M., Tuchnyj, V.P. & Malinovskij, V.V. (2007). Novye tehnologii – za chistoe zemledelie. MV tehnologii v narodnom hozyajstve, 6, 76–79. (in Russian).
Shevchenko, O.I. (1999). Resursozberigayucha tehnologiya viroshuvannya yachmenyu yarogo u pravoberezhnomu Lisostepu i Polissya Ukrayini. Mater. mizhnar. konf., prisvyachenoyi 90–richchyu Institutu roslinnictva, selekciyi i genetiki im. V. Ya. Yur'yeva UAAN, 88–91 (in Ukrainian).
Shurley, W.D. (1987). Economics of legume cover crops in corn production. The role of legume in conservation tillage systems, 152–153.
Skidan, V.O., Popov, S.I., Cehmejstruk, M.G. & Voronko, L.Yu. (2005). Produktivnist pivovarnih sortiv yarogo yachmenyu v zalezhnosti vid strokiv sivbi Visnik SNAU. Ser. “Agronomiya i biologiya”, 11/12, 66–69 (in Ukrainian).
Smetanko, O.V. (2017). Efektivnist elementiv biologizaciyi v tehnologiyi viroshuvannya ozimoyi pshenici v umovah Pivdennogo Stepu Ukrayini. Thesis of Doctoral Dissertation. Kharkiv State Agrarian Unviersity m. V.V. Dokuchayeva. Harkiv (in Ukrainian).
Storchous, I. (2013). Protruyuvannya nasinnya – osnovnij zahid dlya kontrolyu hvorob. Propoziciya, 9, 78–81.
Strona, I.G. (1984). Doposevnaya i predposevnaya obrabotka semyan selskohozyajstvennyh kultur. Teoriya i praktika predposevnoj obrabotki semyan, Kiev, 5–16 (in Ukrainian).
Sudenko, V.Yu. (2016). Posivni yakosti ta vrozhajnist nasinnya pshenici m'yakoyi yaroyi zalezhno vid peredposivnoyi obrobki protrujnikami ta mikrodobrivami. Mironivskij visnik, 3, 160–166 (in Ukrainian).
Tehnologiya mikrohvilovoyi obrobki nasinnya silskogospodarskih kultur. (2009). Kiyiv, Agrarna nauka (in Ukrainian).
Timoshenko, O.P., Homenko, G.V., Vokogon, V.V. & Tuchnij, V.P. (2009). Vpliv peredposivnoyi obrobki mikrohvilyami ta diazofitom nasinnya yaroyi pshenici na urazhennya korenevimi gnilyami ta urozhajnist kulturi. Mikrovolnovye tehnologii v narodnom hozyajstve, 7/8, 78–81 (in Ukrainian).
Turenko, V.P., Bilyk, M.O., Zhukova, L.V., Stankevych, S.V., Zayarna, O.Yu., Lukhanin, I.V., Oleynikov, Ye.S., Batova, O.M., Goryainova, V.V., Poedinceva, A.A. (2019). Dependence of species composition and development of root rots pathogens of spring barley on abiotic factors in the Eastern Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology, 9*(2), 179–188
Vladykin, I.R. (1999). Povyshenie effektivnosti predposevnoj obrabotki semyan ovoshnyh kultur ultrafioletovym izlucheniem. Thesis of Doctoral Dissertation. Moscow (in Russian).
Yevtushenko, M.D. & Maryutin F.M. (2001). Pesticidi i tehnologichni zasobi yih zastosuvannya. Kharkiv, 347 (in Ukrainian).
Zakharchuk, N.A., Dolya, M.M., Polozhenets, V.M., Zhuravska, I.A., Tsuman, N.V., Stankevych, S.V., Nemerytska, L.V., Rozhkova, T.O., Chayka, O.V., Popova, L.V. (2020). Producing of potato varieties resistant to fusarial wilt by cell selection. Ukrainian Journal of Ecology, 10(1), 289–291.
Zazimko, M.I., Monastyrskaya, E.I., Kirienkova, A.E. & Shulyakovskaya, L.N. (1996). Nuzhno li protravlivanie semyan. Zashita i karantin rastenij, 10, 6–9 (in Russian).
Zhukova, L.V., Stankevych, S.V., Turenko, V.P., Bezpal'ko, V.V., Zabrodina, I.V., Bondarenko, S.V., Poedinceva, A.A., Golovan, L.V., Klymenko, I.V., Melenti, V.O. (2019). Root rots of spring barley, their harmfulness and the basic effective protection measures. Ukrainian Journal of Ecology, 9(2), 232–238.
Zubova, R.A. (2013). Obosnovanie rezhimov predposevnoj obrabotki semyan s tverdoj obolochkoj ultrazvukom i elektromagnitnym polem sverhvysokoj chastoty. Thesis of Doctoral Dissertation. Krasnoyarskij gosudarstvennyj agrarnyj universitet. Krasnoyarsk (in Russian).

Citation:
Bezpal'ko, V.V., Stankevych, S.V., Zhukova, L.V., Zabrodina, I.V., Turenko, V.P., Horyainova, V.V., Poedinceva, A.A., Batova, O.M., Zayarna, O.Yu., Bondarenko, S.V., Dolya, M.M., Mamchur, R.M., Drozd, P.Yu., Sakhnenko, V.V., Matsyura, A.V. (2020). Pre-sowing seed treatment in winter wheat and spring barley cultivation. *Ukrainian Journal of Ecology, 10*(6), 255-268.